Recent highlights and future plans

Frank Petriello

ANL DOE review
May 25, 2011

2010-2011 publications

- An exclusive soft function at next-to-next-to-leading order

Y. Li, S. Mantry, F. Petriello, ANL-HEP-PR-11-35

- Handbook of LHC Higgs cross sections I: Inclusive observables

F. Petriello, co-editor of gluon-fusion chapter, arXiv:1101.0593

- FEWZ 2.0: a code for hadronic Z production at next-to-next-to-leading order

R. Gavin, Y. Li, F. Petriello, S. Quackenbush, arXiv:1011:3540

- Transverse momentum distributions in the non-perturbative region

S. Mantry, F. Petriello, arXiv:1011:0757

- Transverse momentum distributions from effective field theory

S. Mantry, F. Petriello, PRD 83:053007 (2011)

- Precise predictions for Higgs production in models with color-octet scalars

R. Boughezal, F. Petriello, Nuc. Phys. Proc. Suppl. 205-206 (2010)

- Color-octet scalar effects on Higgs boson production in gluon fusion

R. Boughezal, F. Petriello, PRD 81:114033 (2010)

- Factorization+resummation of Higgs boson differential distributions in SCET

S. Mantry, F. Petriello, PRD 81:093007 (2010)

2010-2011 talks & activities

- Theory co-convener, joint ATLAS-CMS-theory working group on Higgs cross sections

- Organizer: 2011 LoopFest X (w. R. Boughezal), 2010 CERN theory institute on higher-order corrections, 2010 Aspen summer workshop on QCD (w. E. Berger)

- Reviewer on DOE Intensity Frontier panel, 2010

- Invited/plenary talks: 4th Higgs cross section workshop (BNL), Precision measurements of α_S (MPI-Munich), The Physics of W and Z bosons (BNL), 3rd Higgs cross section workshop (CERN), LoopFest IX (Stony Brook), CDF-D0-Theory meeting on Higgs systematics (Fermilab), Loops & Legs 2010 (Woerlitz, Germany), Emerging problems in particle physics (CUNY), invited review on QCD, 2010 APS meeting (DC)

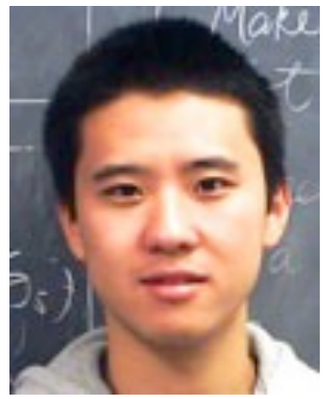
- 2010 Zuoz summer school lectures on QCD

- Colloquia/seminars at Buffalo, BNL, JHU/Maryland, Chicago, Michigan, Heidelberg, Fermilab, Indiana, SLAC, ...

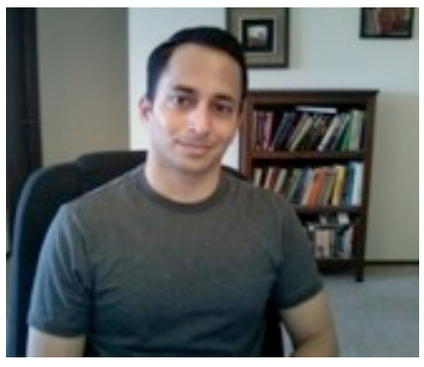
- Upcoming: plenary talks on Higgs/QCD at Physics at the LHC (Perugia), Lepton-Photon (Mumbai); invited review on EW physics at DPF 2011; 2011 CTEQ summer school lectures on Higgs physics

Flow of students/postdocs

R. Gavin: UW-Madison student, frequent ANL visitor⇒ postdoc at PSI with M.Spira, fall 2011



Y. Li: NU student, at ANL ~2 days/week ⇒ planned graduation summer 2012



S. Mantry: NU/ANL LHC theory initiative fellow, starting fall 2011

X. Liu: ANL/NU joint postdoc, starting fall 2011

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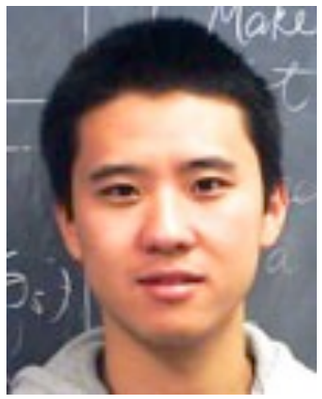
NU connection makes it possible to get them to ANL



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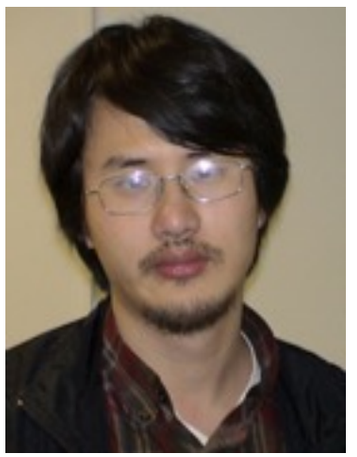

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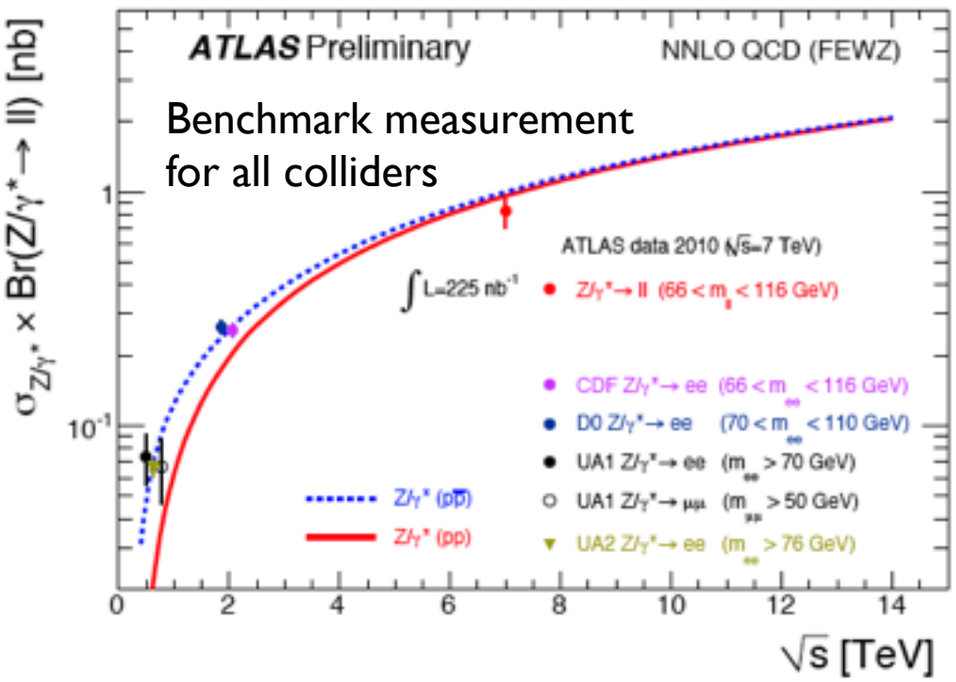
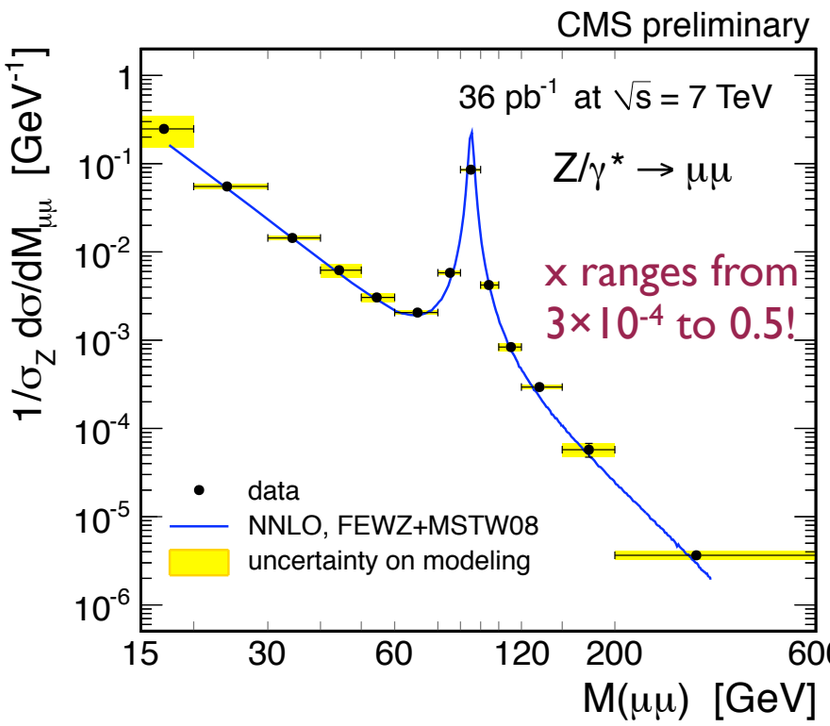
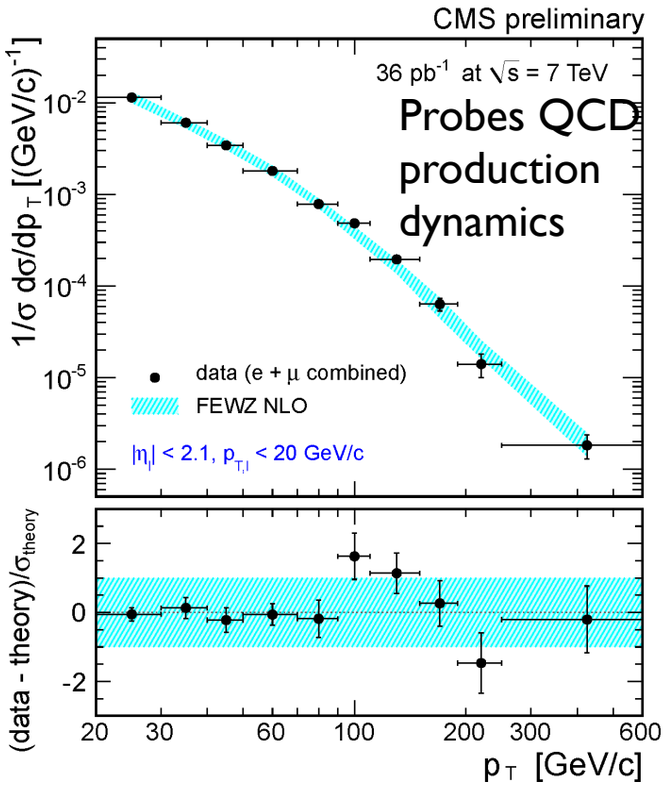
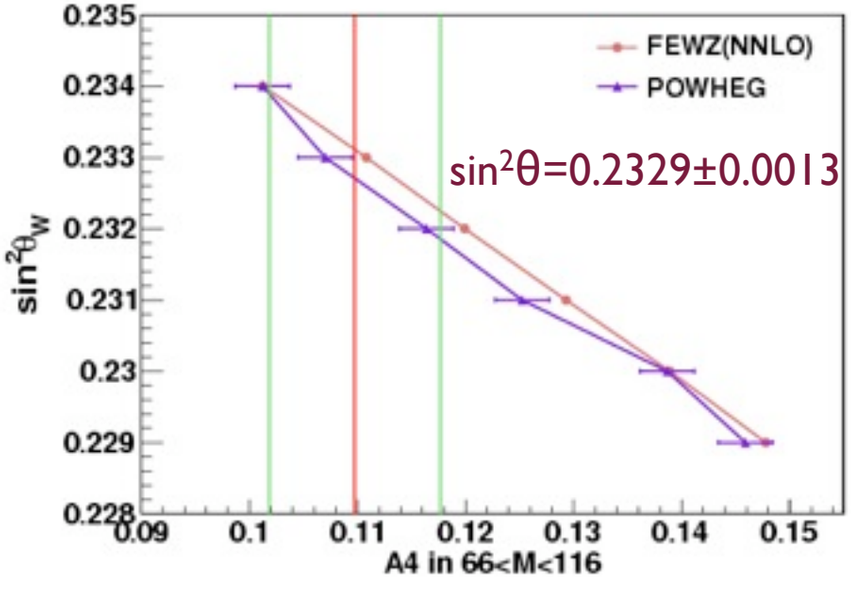
Diversity of EW physics







Fundamental SM parameter determination: CDF



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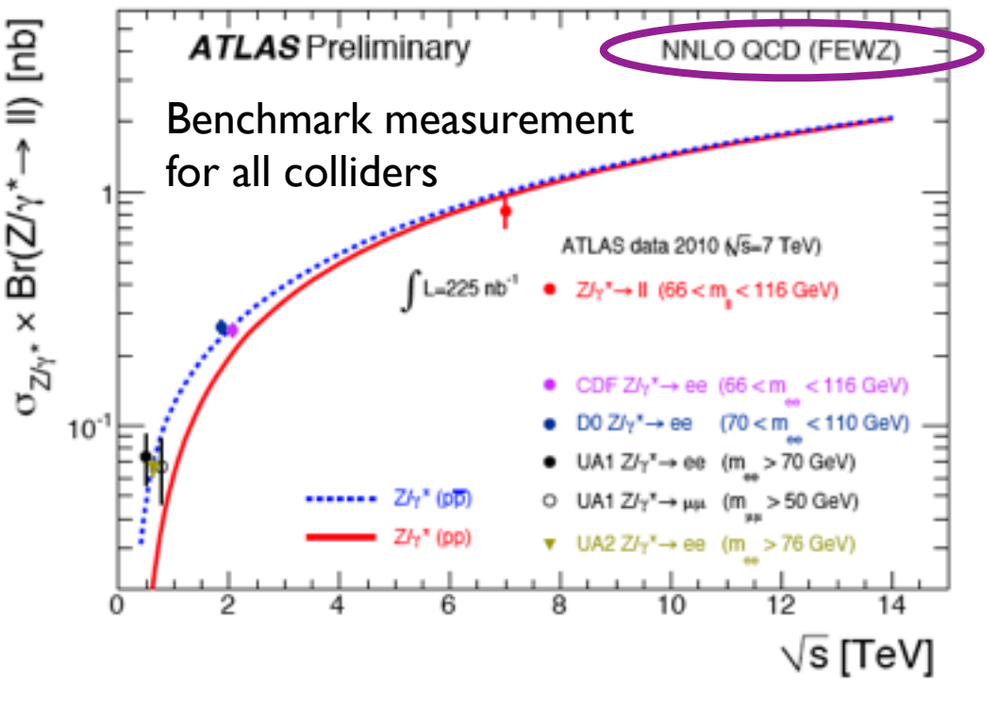
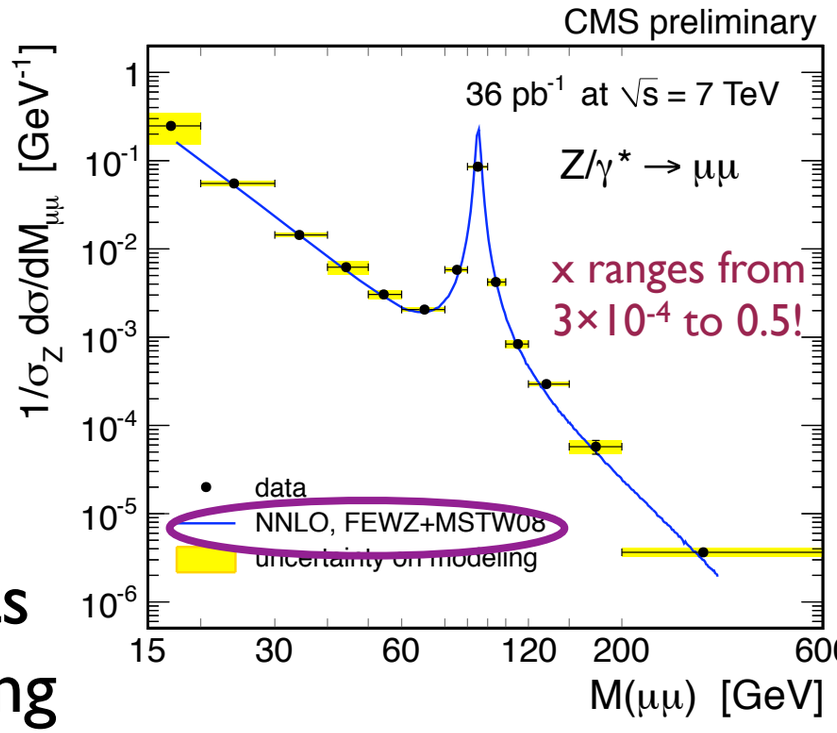
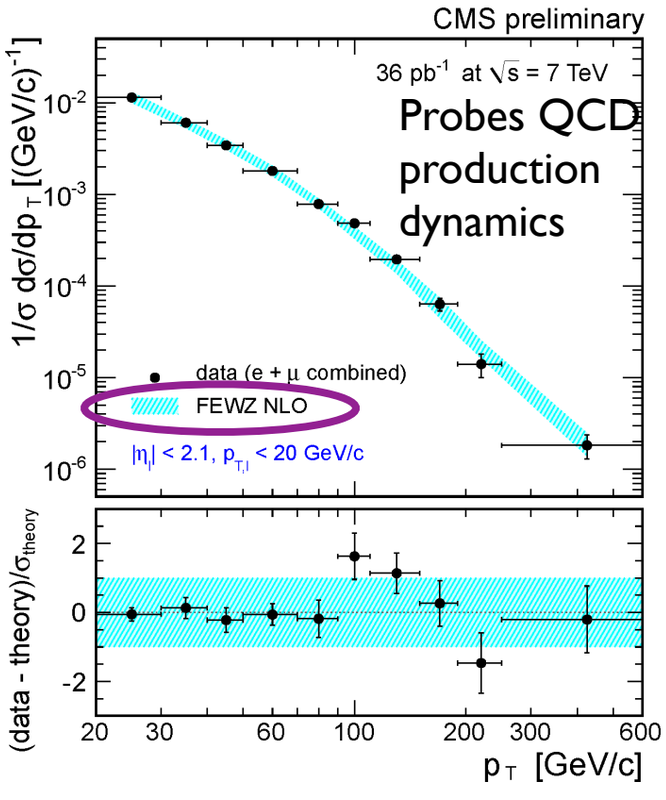




All such measurements have something in common: **FEWZ**



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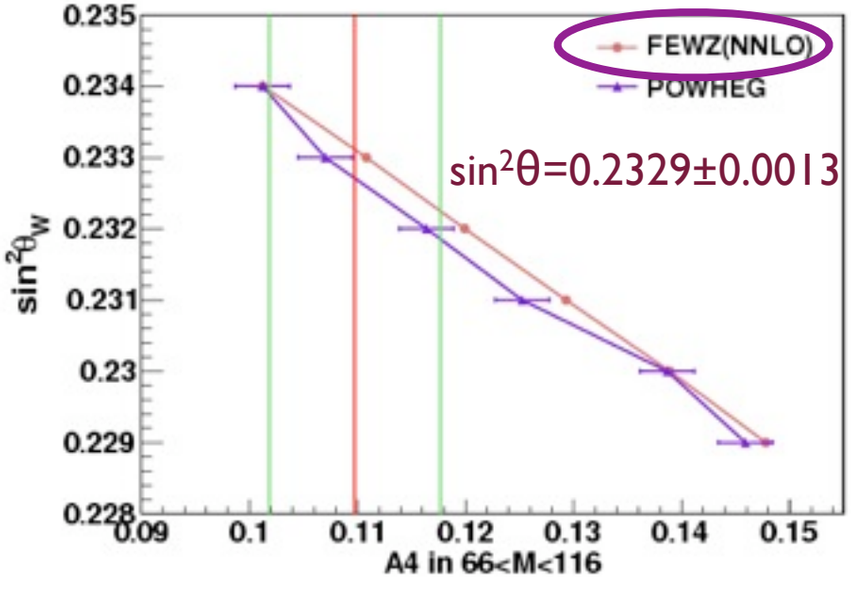
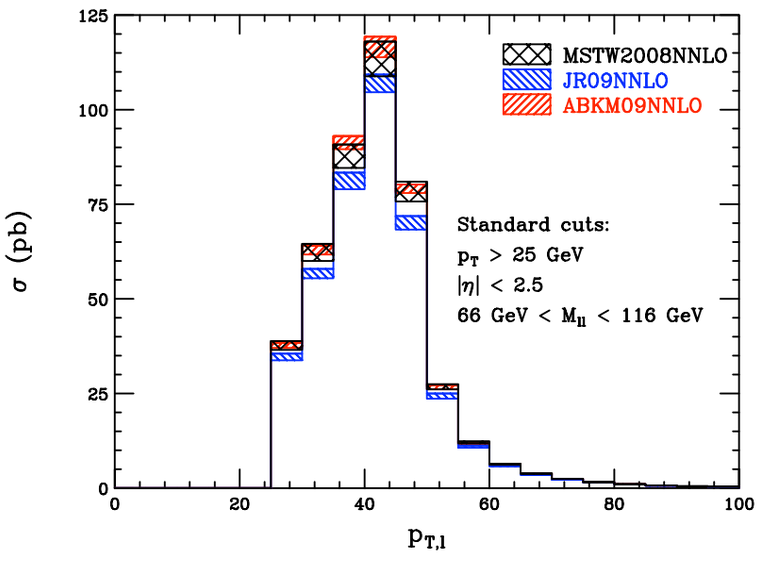


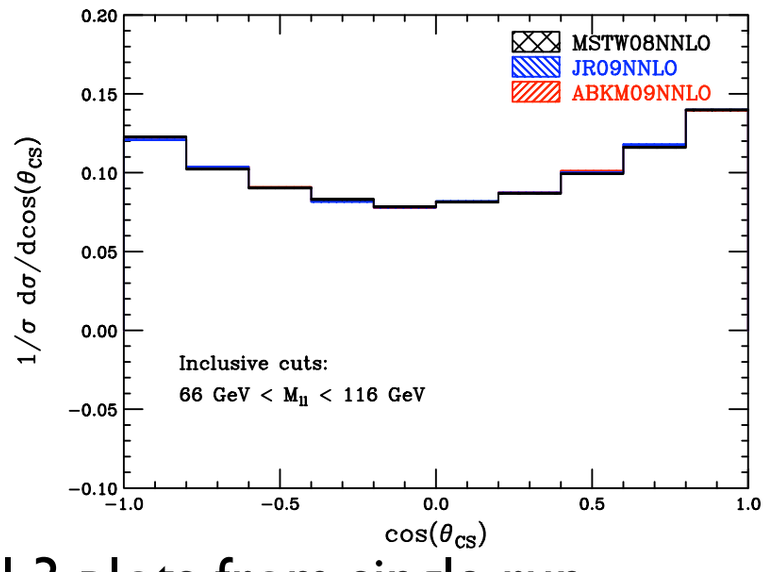
Fully Exclusive W and Z

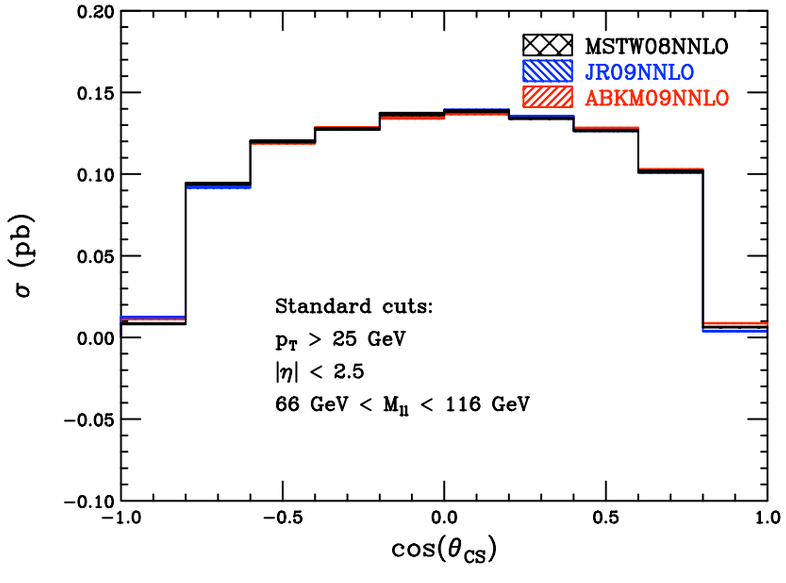
- Original NNLO calculation and program: K. Melnikov, FP (2006); code inefficiency severely limited applications
- Complete re-write with major improvements

Gavin, Li, FP, Quackenbush
arXiv:1011:3540

- ☑ fills histograms of multiple, arbitrary variables during single run
- ☑ parallelization of integration routines
- ☑ PDF reweighting to obtain errors for all observables
- ☑ Optimized sector combination based on correlation study







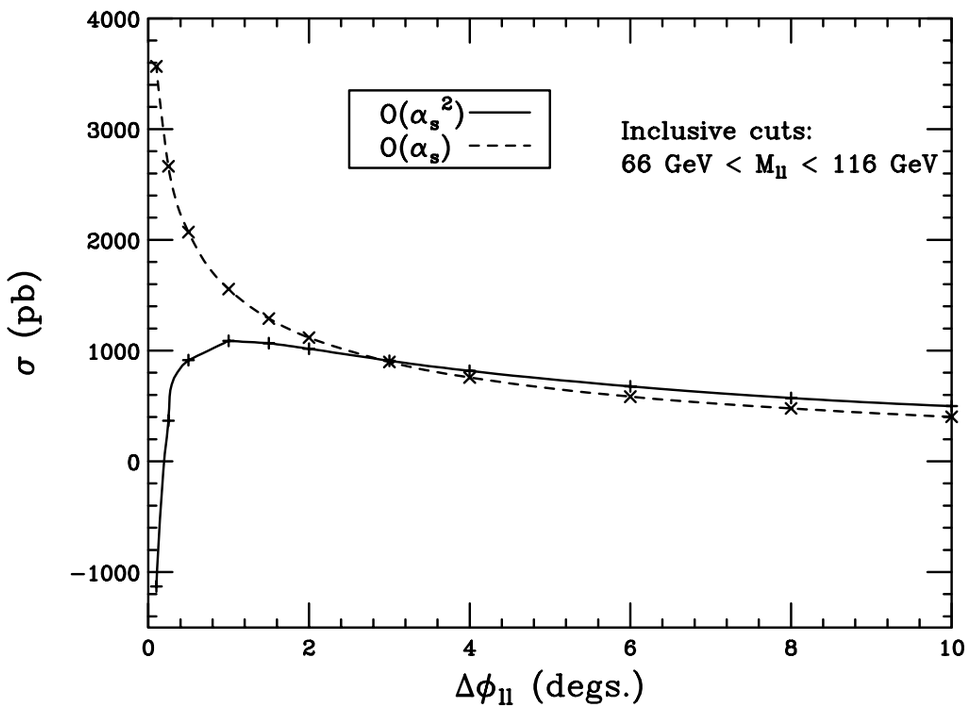
all 3 plots from single run

- 3 of previous 4 studies (p_T, M_{ll}, $\sin^2\theta$) not possible with old FEWZ

Future FEWZ plans

- Incorporation of NLO EW effects (w. Y. Li): primary reason is to have FSR+QCD in single program (avoid unfolding for experiment⇔theory comparison)
- Study of jet vetoes in W/Z cross sections as input to Higgs
- Can we tame our weight(s) and generate parton-level events?
- Further involvement with experimental studies

For example:



Gavin, Li, FP, Quackenbush
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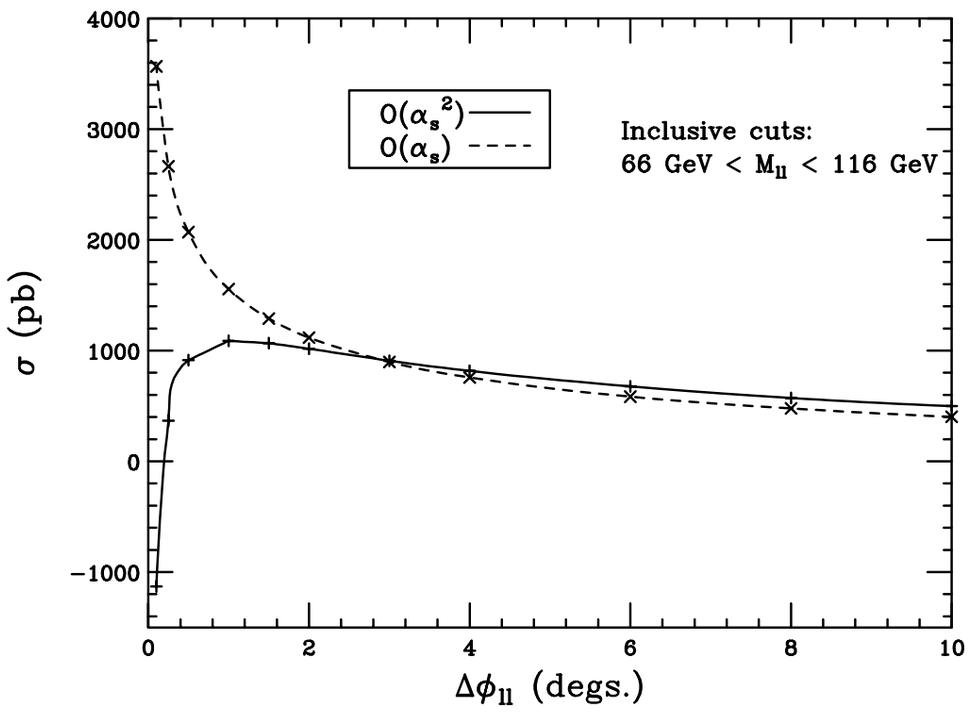
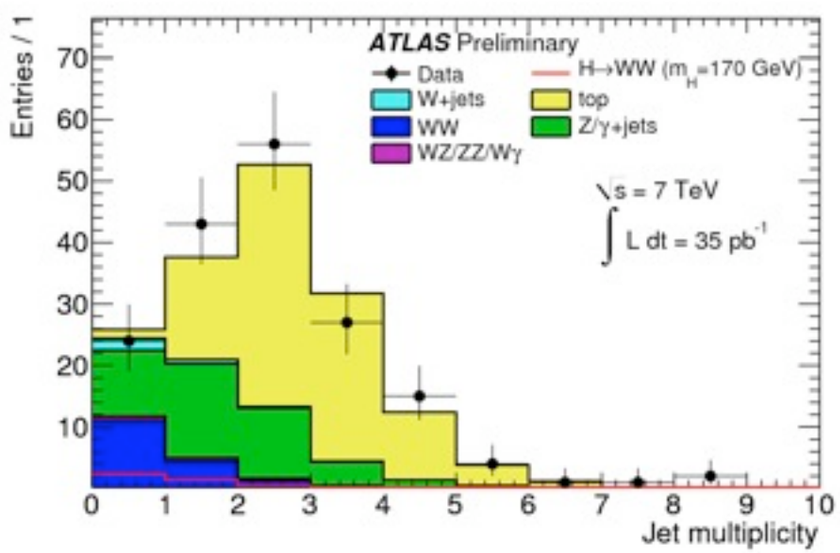


Limited personnel to improve FEWZ, help in physics studies, assist experimentalists when he goes... funds to support a 0.5-1 postdoc position, with Monte Carlo focus, increase for this effort?

Gavin, Li, FP, Quackenbush
arXiv:1011:3540

Recent+planned Higgs results

- Editor, gluon-fusion chapter of CERN Yellow Report on Higgs physics arXiv:1101.0593 (some original ideas+calculations also went into this... JHEP 0904 (2009) 003 in collaboration with R. Boughezal, see her talk next for details)
- "BNL accord" for treatment of jet-veto uncertainty on Higgs cross sections (with F. Tackmann, M. Grazzini, A. Korytov, J. Qian, R. Tananka)
- But... no studies have been done on how underlying event shifts events between 0, 1 jet bins; no systematic way of estimating UE uncertainty, combining it with perturbative error (work in progress with M. Grazzini, F. Krauss and SHERPA team to address this)

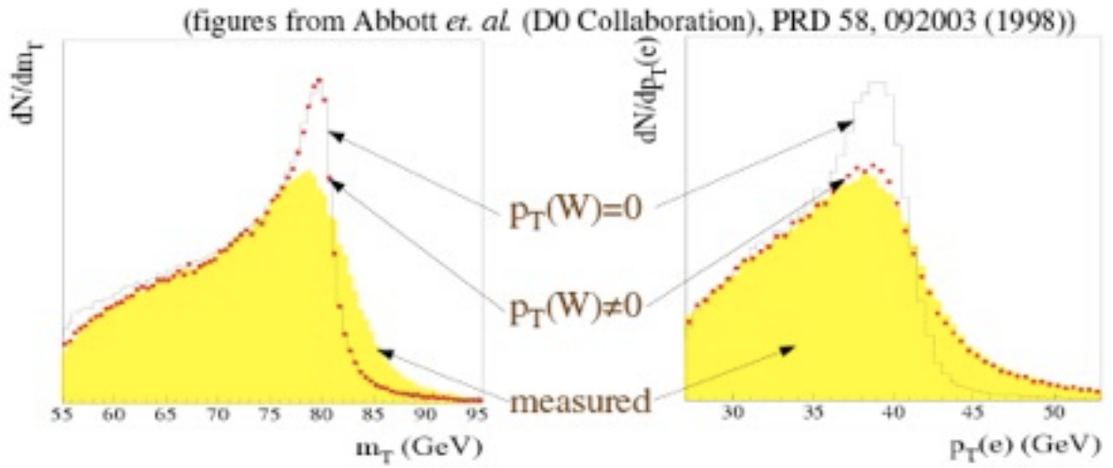


⇐25 GeV jet definition planned

Low-p_T distributions

- Many reasons to understand low p_T production of W, Z, Higgs

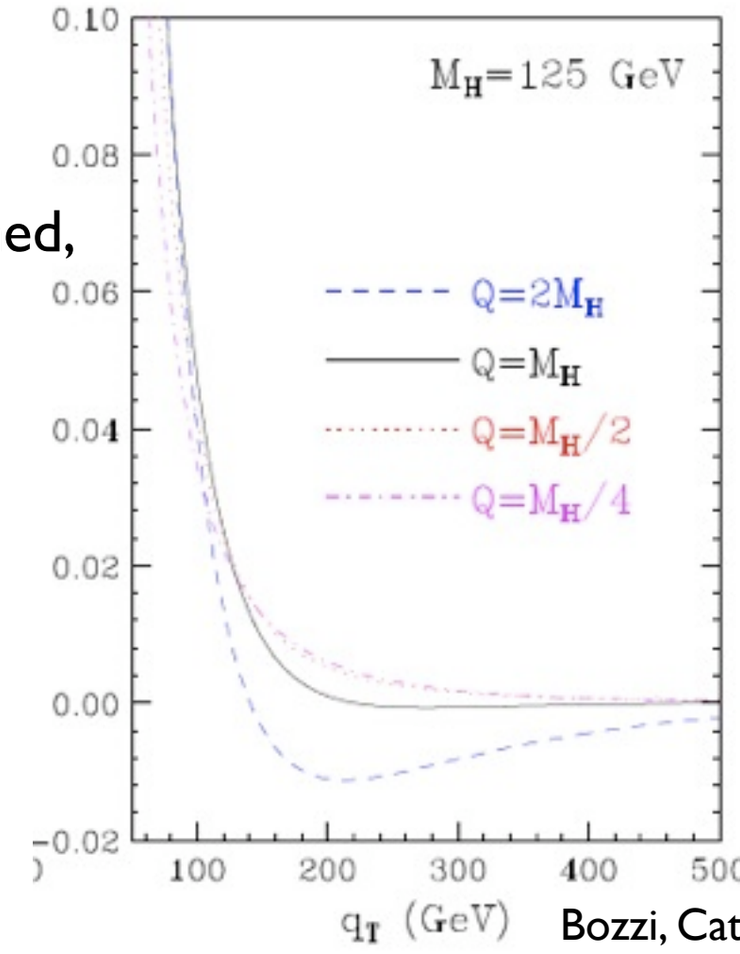
M_W measurement



$$\frac{1}{\sigma}\frac{d\sigma}{dp_T^2} \simeq \frac{1}{p_T^2}\left[A_1\alpha_S \ln\frac{M^2}{p_T^2} + A_2\alpha_S^2 \ln^3\frac{M^2}{p_T^2} + \ldots + A_n\alpha_S^n \ln^{2n-1}\frac{M^2}{p_T^2} + \ldots\right]$$

$$\frac{d^2\sigma}{dp_T\,dY} = \sigma_0 \int \frac{d^2b_\perp}{(2\pi)^2} e^{-i\vec{p}_T\cdot\vec{b}_\perp} \sum_{a,b} \left[C_a \otimes f_{a/P}\right](x_A, b_0/b_\perp)\left[C_b \otimes f_{b/P}\right](x_B, b_0/b_\perp)$$
$$\times \exp\left\{\int_{b_0^2/b_\perp^2}^{\hat{Q}^2} \frac{d\mu^2}{\mu^2}\left[\ln\frac{\hat{Q}^2}{\mu^2} A(\alpha_s(\mu^2)) + B(\alpha_s(\mu^2))\right]\right\}.$$

b-space leads to instabilities in matching resummed, fixed-order



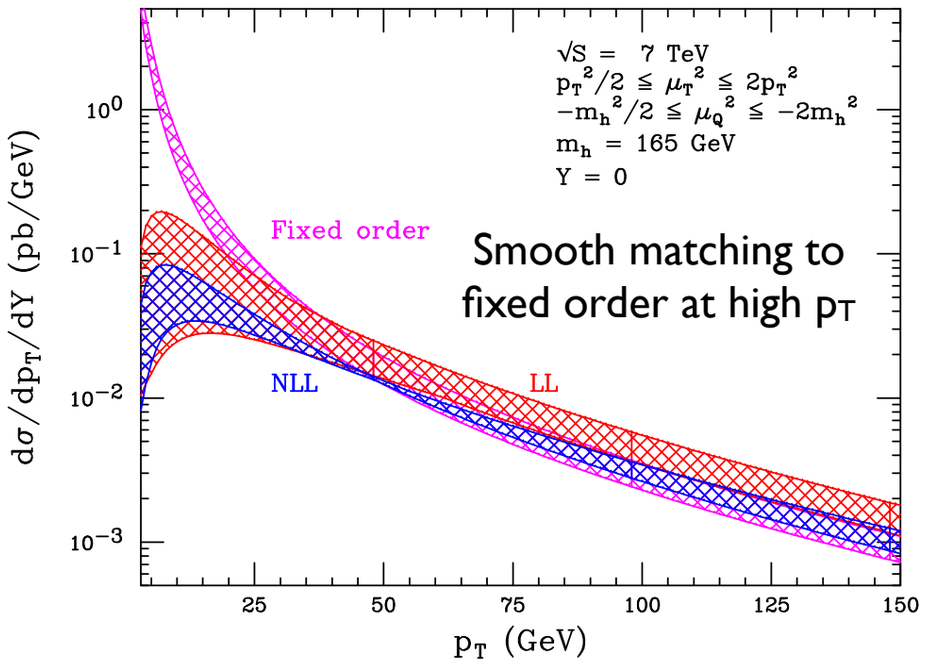
Bozzi, Catani, de Florian, Grazzini 2005

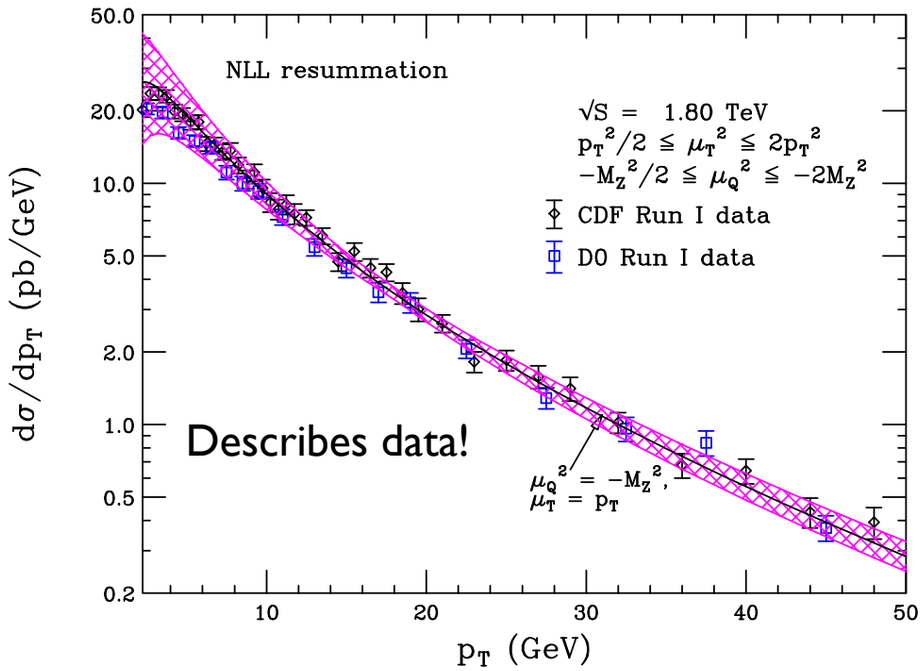
"You cannot use [resummed calculation] to re-weight Monte Carlos above the low p_T region"
-M. Grazzini, 2011 BNL Higgs workshop

EFT approach

- With S. Mantry, have established a new approach based on soft-collinear effective theory during the past year

PRD 81:093007 (2010); PRD 83:053007 (2011); arXiv:1011:0757; ANL-HEP-PR-11-35 (with Y. Li)





☑ Operator definitions for all objects in factorization theorem:

$$J_n^{\alpha\beta}(\omega_1, x^-, x_\perp, \mu) = \sum_{\text{initial pols.}} \langle p_1 | \left[g B^A_{1n\perp\beta}(x^-, x_\perp) \delta(\bar{\mathcal{P}} - \omega_1) g B^A_{1n\perp\alpha}(0) \right] | p_1 \rangle$$

$$J_{\bar{n}}^{\alpha\beta}(\omega_1, y^+, y_\perp, \mu) = \sum_{\text{initial pols.}} \langle p_2 | \left[g B^A_{1n\perp\beta}(y^+, y_\perp) \delta(\bar{\mathcal{P}} - \omega_2) g B^A_{1n\perp\alpha}(0) \right] | p_2 \rangle$$

$$S(z, \mu) = \langle 0 | \bar{T} \left[\mathrm{Tr} \left(S_{\bar{n}} T^D S_{\bar{n}}^\dagger S_n T^C S_n^\dagger \right)(z) \right] T \left[\mathrm{Tr} \left(S_n T^C S_n^\dagger S_{\bar{n}} T^D S_{\bar{n}}^\dagger \right)(0) \right] | 0 \rangle .$$

☑ Rapidity divergences (Chiu, Jain, Neill, Rothstein) naturally regulated by external kinematics in this method

Future SCET plans

- NNLL resummation in our unintegrated formalism will appear shortly; have objects to needed order ANL-HEP-PR-11-35

$$
\begin{aligned}
s_r^{(2)}(q^+,q^-,b_\perp,\mu) \;=\; & C_F N_F \left\{ -\left(\frac{41}{162}-\frac{5\pi^2}{144}-\frac{5}{36}\zeta(3)\right) L_{0,0} + \left(\frac{7}{27}-\frac{\pi^2}{36}\right) L_{0,1} \right. \\
& -\frac{5}{18} L_{0,2} + \frac{1}{12} L_{0,3} - \left(\frac{1}{6} T(b_\perp\sqrt{q^+q^-}) + \frac{5}{18} J_0(b_\perp\sqrt{q^+q^-})\right) L_{1,1} \\
& \left. +\frac{1}{6} J_0(b_\perp\sqrt{q^+q^-}) L_{0,2} \right\} + \\
& C_F C_A \left\{ \frac{\zeta(3)}{36} L_{0,0} - \frac{11\pi^2}{144} L_{0,1} + \frac{11}{24} L_{0,3} - \frac{11}{12} T(b_\perp\sqrt{q^+q^-}) L_{1,1} \right. \\
& \left. +\frac{1}{12} J_0(b_\perp\sqrt{q^+q^-}) L_{1,2} \right\}.
\end{aligned}
$$

$$
\begin{aligned}
\gamma_S^{(2)} \;=\; & \left\{ C_F N_F \left[-\left(\frac{14}{27}-\frac{\pi^2}{36}\right) L_{0,0} + \frac{5}{9} L_{0,1} \right] + \right. \\
& \left. C_F C_A \left[\left(\frac{101}{27}-\frac{11\pi^2}{72}-\frac{7}{2}\zeta(3)\right) L_{0,0} - \left(\frac{67}{18}-\frac{\pi^2}{6}\right) L_{0,1} \right] \right\}
\end{aligned}
$$

- Ready for first LHC data; already discussing with CMS EW group on comparing with our results
- A few more ideas/extensions along these lines in the works... Sonny arrives in the fall, hope to get Xiaohui Liu involved and learn from him too

Time prevents me from discussing:

- Tackling the infrared problem at NNLO (also in collaboration with R. Boughezal, see her talk next)
- Other work on BSM effects in Higgs physics (in collaboration with R. Boughezal, see her talk next)
- Some ideas on spin determination of new resonances at the LHC (work with T.C. Huang, a new student at NU)